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Paleoepidemiology, Healing, and Possible Treatment of Trauma in the Medieval Cemetery Population of St. Helen-on-the-Walls, York, England

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ABSTRACT Traumatic lesions are commonly found in the archeological record and have potential to provide insight into the lives of past populations. This paper examines patterns of long bone fractures in the British medieval population of St. Helen-on-the-Walls from York (approximately 1100–1550) in an effort to determine patterns of healing and evidence for treatment. Long bones were macroscopically and radiologically examined. Clinical data were used to assess whether a fracture had successfully or unsuccessfully healed. The results indicate that fractures of the radius and ulna were most common. Males displayed more fractures than women. Most fractures were healed, well aligned, and without substantial deformity. Lack of evidence for deformity in bones likely to be severely affected by fracture implied that immobilization and possibly reduction was practiced on even the poorest residents of the medieval city.

Traumatic lesions are common abnormalities observed in skeletal populations. Reports of trauma, however, are often limited to case studies and tend to highlight cranial trauma or postcranial fractures clearly associated with violence (e.g., Wells, 1963; Courville, 1965a,b; Manchester and Elmhirst, 1980). The overall frequency rates within a given population (e.g., Manchester, 1978; Wells, 1982; Zivanovic, 1984) or changes in frequency rates over time and between populations (e.g., Wood-Jones, 1910; Brothwell, 1961; Angel, 1974; Steinbock, 1976; Grimm, 1980, 1983; Jurmain, 1983, 1991) are also commonly explored. There is, however, a current trend toward placing trauma into a broader biocultural perspective (e.g., Merbs, 1983; Roberts, 1991; Lovejoy and Heiple, 1981). These studies have attempted to explore the etiology of fractures and the biological and sociocultural environment within which the population operated.

Consideration of fracture types, healing patterns, and complications help build inferences concerning the etiology of trauma and the possibility of treatment. Lovejoy and Heiple (1981), for instance, in their analysis of the Libben site, explore the rate of fractures for particular bones and the presence of healing and distortion. They infer from their data that the Late Woodland population successfully treated fractures. Similarly, Merbs (1983) in his examination of the Sadlermiut weaves information concerning cultural behavior with the frequency and patterns of trauma detected within the population.

The assessment, however, of archeological material can be difficult to interpret. Observations of dry bone specimens pose several

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limitations. First, determining fracture frequency rates can be hindered by fragmentary skeletal remains or poor preservation. Even with good preservation, cases of perimortem fracture may pass undetected since their appearance can mimic postmortem damage. Conversely, well-remodeled fractures of long bones (including stress fractures) can pass undetected during macroscopic and x-ray investigation. Well-remodeled lesions can make the determination of fracture type difficult. Determining the age of the individual when the trauma occurred is also problematic, if not impossible in most instances. Lastly, inferring that a fracture was treated is particularly difficult since splinted bones are rarely found and materials used for treatment were probably biodegradable.

Notwithstanding the limitations, the potential for the study of traumatic lesions in human skeletal remains is considerable (Roberts, 1988). This paper examines the patterns of traumatic lesions in adults, specifically long bone fractures, within a late medieval British cemetery population from St. Helen-on-the-Walls, York. By combining paleopathological information with available archeological and historical data, our goal is to understand the etiology of the lesions and to assess the possibility of treatment of fractures in medieval Britain.

MATERIALS AND METHODS

The sample

The late medieval skeletal material from the cemetery of St. Helen-on-the-Walls (approximately AD 1100–1550) in York, England, was chosen for this study for several reasons. First, the total population (n = 1,014) provided reasonable sample sizes. Second, the quality of preservation of the bones allowed for macroscopic and radiographic assessment (Dawes and Magilton, 1980). Lastly, extensive archeological and historic research, pertaining to this and other medieval British urban centers, provided insight into the biological and sociocultural environment.

The St. Helen-on-the-Walls cemetery yielded total of 1,014 discrete individuals (Grauer, 1989), representing two-thirds of the original graveyard (Dawes and Magilton, 1980). Of the 685 adults, 334 were assigned to specific age-at-death intervals; 351 could be classified only as adult (20+ years old). The determination of age at death was made using as many independent techniques as possible, including dental eruption, formation and attrition rates (Moorees et al., 1963a,b; Miles, 1963; Brothwell, 1981, 1989; Lovejoy, 1985), epiphyseal and sutural fusion (McKern and Stewart, 1957; Krogman and Iscan, 1986; Ubelaker 1989a,b), and pubic symphyseal morphology (Todd, 1921a,b). A total of 533 adult skeletons were assigned a sex (with or without the further assignment of an age-at-death interval) using independent assessments of dimorphic features of the os coxae and cranium (Meindl et al., 1985; Buikstra and Meilke, 1985; Bass, 1987; Ubelaker, 1989a).

As seen in Table 1, the highest proportion of skeletons were placed within the 25–34.9 age-at-death interval. This mortality pattern, along with documentary evidence, suggested from past research that adult migration was an important demographic feature (Grauer, 1991a). The adult mortality pattern by sex (Table 1) indicated that the peak age-at-death for females occurred at 25–34.9 years old and at 35–45 years old for males, a statistically significant difference (Grauer, 1991a). This difference was attributed by Grauer (1991b) to the effects of delayed age at marriage (and thus maternity) and the high rate of female immigration.

Recording of fractures

The term *fracture* refers to traumatic events which lead to a complete or partial break in the continuity of a bone. There are many types of fractures discussed in clinical literature (Watson-Jones and Coltart, 1976; Ostrum et al., 1994). Causes of fracture, as well as the healing process, are also well documented (Rockwood and Green, 1975; Crawford-Adams, 1983). The type of fracture an individual sustains will give an indication of the type of force that acted upon the bone (Merbs, 1989). Transverse fractures, for instance, are caused by direct impact to a particular area, while oblique fractures are caused by direct force applied at a distance from the site of the fracture. In both

TABLE 1. Mortality patterns of skeletons from the St. Helen-on-the-Walls cemetery population

			Female		Males			
Age at death	n	% total	n	%	n	%	Total	%
0–4.9	90	14.2						
5–9.9	100	15.8						
10–14.9	65	10.3						
15–19.9	51	8.0						
20–24.9	24	3.8	13	7.6	9	6.0	22	6.9
25–34.9	108	17.1	65	38.2	39	26.0	104	32.5
35–44.9	98	15.5	44	25.9	54	36.0	98	30.6
45–54.9	70	11.0	36	21.2	34	22.7	70	21.9
55–64.9	27	4.3	12	7.1	14	9.3	26	8.1
Subtotal	633							
Undeterminable	381							
Total	1,014		170		150		320	

archeological and clinical material it is possible to record most fracture types (Roberts, 1988).

Macroscopic recording. The long bones of all skeletons from St. Helen-on-the-Walls were macroscopically evaluated (n = 4,938). Detailed examinations were made of the shafts of the humerus, radius, ulna, femur, tibia, and fibula, since the debilitating nature of these fractures would more likely compel the sufferer to seek treatment, if available, than would fractures of the smaller bones of the hands or feet.

Fractures, when detected, were recorded by position along the shaft (i.e., proximal third, mid shaft, distal third). Location of a fracture can occasionally be associated with soft tissue complications (Bodine and Lieber, 1994) and influence the healing process. The type of fracture was also recorded. The association of specific types of fractures with particular actions, occupations, and accidents is well noted in the clinical literature (Merbs, 1989) and holds promise for archeological evaluation. Identifying the type of fracture can lead to the identification of the cause, an assessment of the ability to heal, and the potential for complications (Roberts, 1988).

The presence and results of healing were also recorded. Comparisons between fractured and unaffected bone (when available) from the same individual provided a means to recognize and quantify loss of length (or shortening). Bone shortening indicated that an overlap of the fracture fragments had occurred and subsequently suggested that fracture reduction was not attempted or had failed. Rotational or linear deformity was also recorded by comparing the fractured bone with the contralateral side (or, if unavailable, with a normal reference bone). The presence of this deformity was assumed to indicate that the fracture had not been treated or had been treated ineffectively. Since linear deformity is, and would have been in antiquity, easier to reduce than a rotational deviation, associating type of fracture with healing was important.

Alignment of the healed fracture bone was recorded as a means to recognize the practice of reduction and splinting. The presence of good alignment or angulation, good apposition or partial apposition, overlap, or distraction was recorded when possible. Since malalignment and other deformities of healed bone can place stress on adjacent joints, the presence of degenerative joint disease was recorded, even though the development of joint disease could have occurred prior to the fracture.

Evidence of nonspecific infection, appearing as periosteal reaction, was also recorded when associated with a fracture. Periostitis and osteomyelitis occur as complications of compound fractures and can delay or prevent healing. In this study the presence of localized periosteal reaction was assumed to indicate that the fracture was compound and resulted from the direct spread of environmental or commensal organisms from the skin surface to the exposed fractured bone. Nonlocalized periosteal reac-

tion was regarded as unrelated to the fracture.

Radiographic recording. The evaluation of trauma in ancient populations, by necessity, relies heavily on the use of radiography to assess the injury and healing process. Following gross examination, each fracture was radiographed in standard views and in two projections at right angles to each other, anteroposteriorly (AP) and mediolaterally (ML). From each radiograph a determination of fracture type, aspects of healing, and the presence and degree of displacement of fracture fragments was made. The presence of other pathological lesions on the same bone was also noted. Radiographic determination of fracture type is of considerable importance in paleopathology. A well-remodeled bone often masks the type of fracture originally present or, worse, can be misleading.

The presence and/or degree of displacement of each fracture was also recorded. Based on the work of Roberts (1988), the degree of angulation was measured by recording the direction and degree of displacement of the distal fragment using a standard ruler and protractor (Fig. 1). Angulation was recorded as anterior, posterior, medial, or lateral. Bone fracture fragment overlap and apposition (Figs. 2, 3) were recorded by millimeters offset and percent apposition, respectively.

Radiographs and medical records of modern fractures were examined from the National Orthopaedic Hospital, Stanmore, to create a model for determining successful and unsuccessful healing (Roberts, 1988). Modern cases of fracture were included in the study based on three criteria: 1) the patient's fracture was not the result of an accident involving modern technology; 2) the fracture was treated conservatively (i.e., with simple reduction and splinting); and 3) the orthopaedic surgeon concluded that healing was successful. From this data criteria were established for assessing archaeological cases of successful and unsuccessful fracture healing according to the degrees of deformity, overlap of fragments, and angulation (Table 2). A healed fracture of a tibia, for instance, found in the archeological record

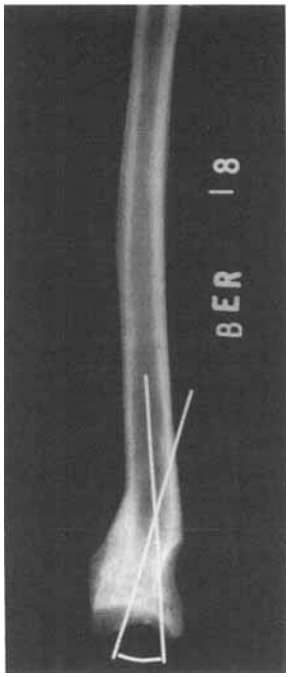

Fig. 1. Measurement of the degree of angulation deformity of a Colles fracture of the radius.

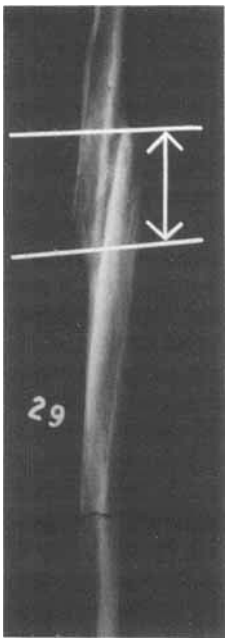

Fig. 2. Measurement of the degree of bone overlap of the fibula.

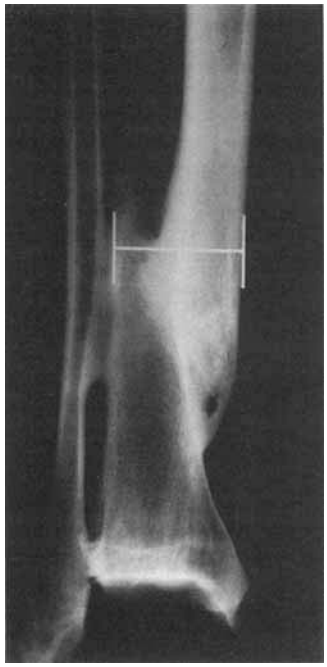

Fig. 3. Measurement of the degree of apposition showing 0% apposition of the tibia.

TABLE 2. Degrees of deformity constituting unsuccessful fracture healing[1]

Bone	Degree of deformity constituting unsuccessful healing[2]
Femur	>30 mm shortening
	>35° linear deformity
	>50 mm overlap
Tibia	>15° linear deformity
	>10 mm overlap
Tibia and fibula	>15° linear deformity
	>35 mm overlap
Humerus	>20° linear deformity
	>15 mm overlap
Radius	>25° linear deformity
	>15 mm overlap
Radius and ulna	>25° linear deformity

[1] Based on Roberts (1988).
[2] Omissions of deformity types within each bone type represent insufficient sample size to determine results.

with over 30 mm of shortening and/or over 35° of linear deformity would be considered a case of unsuccessful healing.

Caution must be exercised when using modern data to interpret archeological fractures. Examples of successful healing in the archeological record, based upon clinical data, might be the result of simple fractures that originally had no overlap, deformity, or lack of apposition rather than the result of reduction and immobilization. Similarly, bones, or sets of bones, when fractured at particular places may or may not be susceptible to overlap or apposition. Lastly, an assumption must be made about the rate and efficiency of fracture healing in past and present populations. The clinical data concerning fracture healing was derived from a well-nourished modern British population living in favorable conditions. The same may not be true for archeological populations, and therefore successful or unsuccessful healing may reflect poor health rather than merely the presence and practice of treatment. If treatment of fractures is to be inferred from archaeological populations, it must be recognized in bones likely to be displaced when fractured and in populations where diet, and thus health, might generally be poor.

Comparative populations. The results from St. Helen-on-the-Walls were compared to five other medieval urban cemetery populations in Britain. The sites selected for comparison were determined by the sample size and degree of preservation, the archeologically determined date of the cemetery use, and their urban-derived context. Comparisons relied upon data collected by the principle investigator of each population. Adopted for comparison were the following sites: St. Andrew, Fishergate, in York, consisting of 309 sexed adults dating from the eleventh to twelfth centuries (Stroud and Kemp, 1993); St. Nicholas Shambles, London, consisting of 161 sexed adults dating from the eleventh to twelfth centuries (White, 1988); Blackfriars, Ipswich, Suffolk, consisting of 212 sexed adults dating from AD 1263–1538 (Mays, 1991); Whithorn, Scotland, with 670 sexed adults dating from the medieval period (A. Cardy, unpublished manuscript); and the site of the Medieval Hospital of Chichester, Sussex, which yielded 198 sexed adults (Judd, 1994).

RESULTS

A total of 4,938 long bones was examined from the St. Helen-on-the-Walls skeletal population, representing the remains of

TABLE 3. Frequency of fracture by bone in St. Helen-on-the-Walls

Bone	n	Fractures n	Fractures %	Bone type	Fractures (%)
L humerus	424	3	.7		
R humerus	427	4	0.9	Humerus	0.8
L radius	383	4	1.0		
R radius	387	6	1.5	Radius	1.3
L ulna	372	5	1.3		
R ulna	380	6	1.6	Ulna	1.5
L femur	474	0	0		
R femur	463	1	.2	Femur	0.1
L tibia	431	4	.9		
R tibia	433	2	.5	Tibia	0.7
L fibula	363	5	1.4		
R fibula	362	1	.5	Fibula	0.8
Total	4,938	41	.8		

TABLE 4. Age and sex distribution of individuals displaying long bone fracture in the St. Helen-on-the-Walls cemetery population

Age at death	Females (n)		Males (n)		Total (n)	(%)
20–24.9	0		0		0	0
25–34.9	1		1		2	6.7
35–44.9	3		6		9	30.0
45–54.9	3		0		3	10.0
55+	0		1		1	3.3
Adult (age indeterminable)	5		10		15	50.0
Total	12	(40%)	18	(60%)	30	

1,014 individuals. A total of 41 long bone fractures (0.8%) was macroscopically detected. The fractures represent trauma to 30 individuals, or 2.9% of the population. As Table 3 indicates, most fractures occurred in the right radius and right ulna, whether measured by counting the number of fractures of that bone or measured as a proportion of bones with fractures to bones without fractures. When anatomical elements are pooled to include right and left sides, a slightly different pattern emerges. Here, the radius and ulna appear more frequently subjected to fracture, both in real terms when compared to the number of fractures in other bones and as a proportion of the total number of those particular bones present in the collection.

There were four cases within the St. Helen-on-the-Walls population of long bone fracture of the radius and ulna occurring together in the same individual. There were also four cases of simultaneous fracture of the tibia and fibula. For the radius and ulna, this indicates that approximately 40% of all the fractures of the lower arm involved both bones. For the tibia and fibula, the frequency of four cases of simultaneous fracture represents nearly 67% of all fractures of these bones.

All long bone fractures occur in adults capable of being sexed. Half of these adults could be assigned an age at death (Table 4). The most common age at death for individuals displaying a healed fracture was 35–44.9 years old. While 60% of the incidents of trauma occur in males, the difference was not statistically significant. As indicated in Table 5, the most common fracture was oblique, regardless of the bone affected. This suggests that indirect nontorsional forces were responsible for the trauma. The distal portion of the long bones was the most frequently affected site for fracture. Linear deformity occurred most often (26.8%), but in 25 (61.0%) of the 41 cases of trauma no deformity was noted. No evidence of extreme long bone shortening due to poor shaft apposition was found. This suggests that apposition of fracture fragments in virtually all specimens was probably 50% or more. Importantly, all fractures examined in this population, except for one case of a radius and ulna which failed to unite, were well healed, indicating that the fractures had occurred years prior to the individuals' death.

The evaluation of the presence of periosteal reaction (as an indicator of periostitis or osteomyelitis) (Table 6) found the condition present in 13 (31.7%) fractured bones. The fibula was most commonly affected, constituting 30.7% of all long bones recorded with periosteal reaction. Similarly, 67% of the fibulae with fractures display periosteal reaction. The evaluation of the presence of osteoarthritis in bones with fractures indicates that 7 (43.7%) of the 16 bones with osteoarthritis occur in the radius, representing 70.0% of all fractured radii recorded. No underlying pathological conditions were recognized which would predispose the bone to fracture.

The pattern of fractures in the St. Helen-on-the-Walls population was compared to five other medieval skeletal populations from Britain. As indicated in Table 7, the results obtained from St. Helen-on-the-

TABLE 5. Analysis of fracture patterns from St. Helen-on-the-Walls

	Fracture type				Fracture level			Deformity		
Bone	Oblique	Spiral	Impacted	Transverse	Proximal	Mid	Distal	Linear	Spiral	Absent
Humerus	6	1	0	0	3	1	3	1	1	5
Radius	9	1	0	0	0	4	6	6	1	3
Ulna	8	1	0	2	1	4	6	1	1	9
Femur	1	0	0	0	0	1	0	1	0	0
Tibia	5	1	0	0	1	1	4	1	1	4
Fibula	5	1	0	0	1	1	4	1	1	4
Total	34	5	0	2	6	12	23	11	5	25

TABLE 6. Frequency of periosteal reactions and osteoarthritis in the St. Helen-on-the-Walls population

	Periosteal reaction					Osteoarthritis				
	Present		Absent			Present		Absent		
Bone	n	%	n	%	% total present	n	%	n	%	% total present
Humerus	3	42.9	4	57.1	23.1	2	28.6	5	71.4	12.5
Radius	1	10.0	9	90.0	7.7	7	70.0	3	30.0	43.7
Ulna	3	27.3	8	72.7	23.1	5	45.5	6	54.5	31.3
Femur	0	00.0	1	100	0.0	0	00.0	1	100	0.0
Tibia	2	33.0	4	67.0	15.4	1	16.7	5	83.3	6.25
Fibula	4	67.0	2	33.0	30.7	1	16.7	5	83.3	6.25

Walls do not differ greatly. In four of the six populations the frequency rate of long bone fractures, when calculated from the number of long bones available for examination in the total population, does not exceed 1%. Great similarity is also seen in the proportion of adult individuals with fractures, except for adults buried in the cemetery of the Chicester Hospital. When fractures of a particular bone are examined, the radius and/or humerus appear to be the most commonly fractured long bones.

The pattern of long bone fracture by sex is also similar in these populations. In each population the frequency rate in males surpassed that of females (Table 8). When the data is pooled, males display a frequency of long bone fracture that is almost double that of females.

DISCUSSION

Documentary evidence for medieval urban life

Documentary evidence exists pertaining to the city of York during the period when the cemetery of St. Helen-on-the-Walls was in use (approximately AD 1100–1550). Evidence, however, specifically about these parishioners is comparatively small if not conspicuously absent. This may reflect the economic unimportance and thus the poverty of the St. Helen-on-the-Walls parish compared to other much wealthier parishes in the city (Palliser, 1979, 1980).

Documentary sources provide insights into the socioeconomy of York. Citizens were predominantly merchants and craftsmen (Darby, 1936). By the mid-thirteenth century the cloth industry had declined and the leather industry prospered (Lipson, 1921). The Lay Subsidies of 1377 and 1381 identify almost 100 different crafts within the city and nearly 1000 heads of households (Harvey, 1975).

The occupations and actual numbers of St. Helen-on-the-Walls parishioners at any given time remain a mystery. The names of household heads, along with occupations and number of dependents, are recorded only for the 28 wealthiest parishes in the city. Omitted, or appearing in aggregative form, are those individuals of no fiscal interest to the crown: the clergy, beggars, vagrants, landless poor, servants, and most women and children (Elton, 1969). Indirectly this implies that St. Helen-on-the-Walls parishioners constituted the poorest of York's residents (Bartlett, 1953).

TABLE 7. Patterns of long bone fracture in medieval skeletal populations

Frequency by population	Total population				Adults[1]		
Site	n	Total bones	Bones with fractures	%	Total (n)	Individual with fractures	%
St. Helen-on-the-Walls	1,014	4,938	41	.8	533	30	5.6
St. Nicholas Shambles	234	296	18	6.1	161	8	5.0
Blackfriars	250	1,861	13	.6	212	9	4.2
Fishergate	402	3,235	26	.8	309	50	6.5
Whithorn	1,605	9,563	27	.3	670	55	8.2
Chichester Hospital	351	1,554	41	2.6	198	31	15.7

Frequency by bone	Humerus			Radius			Ulna			Femur			Tibia			Fibula		
Site	N[2]	n[3]	%	N[2]	n[3]	%	N[2]	n[3]	%	N[2]	n[3]	%	N[2]	n[3]	%	N[2]	n[3]	%
St. Helen-on-the-Walls	891	7	.8	770	10	1.3	752	11	1.5	937	1	.1	864	6	.7	725	6	.8
St. Nicholas Shambles	38	2	5.3	57	5	8.8	49	4	8.2	53	2	3.8	50	3	6.0	49	2	4.1
Blackfriars	369	1	.3	370	5	1.4	371	2	.5	393	2	.5	393	2	.5	358	1	.3
Fishergate	528	2	.4	523	4	.8	518	7	.8	577	1	.2	558	3	.5	531	9	1.7
Whithorn	1,650	0	0	1,327	7	.5	1,530	2	.1	2,408	4	.2	1,819	7	.4	829	7	.8
Chichester Hospital	243	2	.8	218	7	3.2	217	6	2.8	228	1	.4	276	6	2.3	111	8	7.2

[1] Includes individuals of unknown sex and/or unknown age at death.
[2] N = total number of bones.
[3] n = total number of bones with fractures in individuals that could be sexed and/or aged.

TABLE 8. Comparisons of fracture frequency by sex in medieval skeletal populations

	Females			Males		
Sites	N[1]	n[2]	%	N[1]	n[2]	%
St. Helen-on-the-Walls	285	11	3.9	247	18	7.3
St. Nicholas Shambles	71	2	2.8	90	6	6.7
Blackfriars	64	2	3.1	148	7	4.7
Fishergate	89	5	5.6	220	15	6.8
Whithorn	356	18	5.1	314	37	11.8
Chichester	70	4	5.7	128	27	21.1
Total	935	42	4.5	1147	110	9.6

[1] N = total number of individuals capable of being sexed.
[2] n = total number of individuals with fracture.

The economic and demographic conditions were partially responsible for the documented squalid environment. Two specific aspects of urban life are often mentioned: the recurrence of catastrophic epidemics and problems with sanitation (Raine, 1893). While famine was a major precursor to disease in virtually all medieval centuries, exacerbated by crowded living conditions, the role of poor sanitation cannot be overlooked. Medieval cities were known for their unsanitary conditions during the best of economic times. York by no means was an exception. Numerous city ordinances suggest that attempts to control the city's sanitation problems were seldom successful.

The paleopathological analysis of the skeletons from the St. Helen-on-the-Walls cemetery has indicated that the environment played a substantial role in disease patterns (Grauer, 1989). The presence of cribra orbitalia and porotic hyperostosis in 58% of the population indicated that iron-deficiency anemia was a common childhood condition (Grauer, 1993). Likewise, 21.5% of the population displayed periosteal reactions, suggesting the presence of nonspecific infection, parasitic infestation, and/or endemic treponematosis (Grauer, 1993).

Etiology of long bone fractures

The overall patterns of long bone fracture frequency, type, and healing, provide another lens through which significant insight

into the environment and conditions facing the poor inhabitants of medieval York can be made. First, it appears that long bone fractures were uncommon. This is not an artefact of poor skeletal preservation since the number of individuals displaying fractures is low among the best preserved group: aged and sexed adults. The lower arm, especially the right side, displayed the greatest number of long bone fractures. Evidence of fracture was found in males more often than in females. These data appear to corroborate the documentary evidence. For instance, the nature of medieval cities as sites of craft production and commerce suggests that the majority of citizens would be employed or engaged in light labor—that is, labor requiring proportionately greater use of the arms than other body parts. Since Calvin (1982) has reported that 90% of humans can be categorized as right-handed, it is not surprising to find that the majority of injuries occurred to this side of the body. It also is no surprise that males more frequently display long bone fractures. Medieval Britain was notoriously patriarchal, denying membership to craft guilds and the participation in many occupations to women under normal circumstances. For women, employment was usually gained in household service or as independent traders (Goldberg, 1986), perhaps minimizing their susceptibility to trauma.

It is difficult to determine the etiology of the fractures in the St. Helen-on-the-Walls population. While the majority of forearm fractures occurred to the middle or distal shafts, the occurrence of transverse fractures is low. Transverse fractures to the ulna in particular can be interpreted as a sign of violence caused by direct blows with angulated force (Crawford-Adams, 1983). These fractures, known as parry fractures, occur as the victim attempts to ward off an offender by shielding his/herself with an arm. Subsequently, the two cases of transverse fracture to the ulna might have been caused by interpersonal violence.

The majority of ulna fractures in this population are oblique. This indicates the presence of an indirect force acting at a distance from the site of fracture, resulting in an uneven bending of the bone. Hence, most of the ulna fractures were likely the result of acute injury provoked by a fall or similar unfortunate occurrence.

The patterns of fractures to the radius present similar results. Most of the fractures occur to the mid or distal shaft, and all except one is oblique. Most fractures occurring to the distal radial shaft appear to be Colles's fractures, a condition caused by static and dynamic forces working against each other, commonly the result of falling on an outstretched arm. The result of this shearing trauma to the radius is the posterior displacement of the distal portion of the bone (Ortner and Putschar, 1981). The presence of this condition suggests again an accidental rather than violent etiology.

The location and type of fracture found in other long bones (humerus, femur, tibia, and fibula) repeat the patterns discussed above. The majority of the fractures are oblique and at the distal ends. While assigning specific causes of trauma is impossible, as is relating the trauma to specific occupations or actions, it appears from the data that long bone fractures suffered in medieval York are remarkably similar to those associated with twentieth-century life. That is, the most commonly fractured long bones are the radius and ulna and the tibia and fibula, and the most common causes are accidents (Buhr and Cooke, 1959; Garraway et al., 1979; Fife and Barancik, 1985).

The possibility of medieval treatment

Evidence for the availability of fracture treatment in late medieval Europe is plentiful (Clark, 1937). There were orthopaedic surgeons, specific individuals known as bonesetters, and barber surgeons who occasionally reduced, manipulated, and splinted bones. While many of the methods of bone repair appear to be based upon Greco-Roman concepts of disease and injury, illustrations exist showing sophisticated methods of fracture treatment. No references to fracture treatment in Britain remain.

Synthesizing modern clinical data on healing with data collected from the St. Helen-on-the-Walls population may provide insight into treatment in Britain. Causes and effects of fractures, along with complications and their effect on healing, are provided by clinical data. Comparing these data with the St. Helen-on-the-Walls population allows for

speculation concerning the treatment of fractures.

Clinical data suggests that fractures of the surgical or anatomical neck of the humerus are usually impacted and, therefore, are stable (Crawford-Adams, 1983). Treatment commonly involves support in a sling with encouragement to exercise the shoulder and elbow joints. Unimpacted fractures are given the same treatment but restricted from movement at the shoulder. Three cases of fracture of the proximal humerus, one at the surgical neck and two at the anatomical neck, were found in the St. Helen-on-the-Walls population. Of these only one appeared to be impacted and had healed well from an oblique fracture. This stable fracture, however, may have been accompanied by subsequent infection, as severe localized periosteal reaction with cortical bone involvement was noted. The two fractures of the anatomical neck were well healed with no sign of infection. One case, however, displayed severe osteoarthritis of the head of the humerus and the glenoid fossa. The bone was also substantially shorter than the other side, indicating that the fracture had occurred at a young age and had disrupted normal length development.

Mid-shaft and supracondylar fractures (located at the distal third of the humerus shaft) usually unite after reduction and immobilization of the bone in a plaster cast. Delayed or non-union, however, occurs more often in the humerus than in any other bone (Campbell, 1937), possibly due to the impossibility of securing complete immobilization of the fracture and/or the difficulty in maintaining coaption of the fragments and preventing a gap between them. Although the weight of the arm can assist with reduction of the fracture, it can also produce a gap between the fragments. Supracondylar fractures are complicated by the risk of damage to the brachial artery, median nerve, and radial nerve. One case of mid-shaft fracture and three cases of supracondylar fracture were recorded in the St. Helen-on-the-Walls population. All cases were well healed. The mid-shaft fracture was spiral and displayed a linear deformity with slight rotation and poor alignment and signs of localized periosteal reaction. Of the three supracondylar fractures, none displayed deformity, only one displayed localized periosteal reaction, and another displayed osteoarthritic changes to the distal articular surface.

The overall assessment of healing patterns of fractures in the humerus leads to the conclusion that in most instances the repercussions of fracture were mild. This finding seems unlikely when the clinical information is considered, unless the sufferers of humerus fractures were particularly lucky in their patterns of healing or if treatment, most likely in the form of immobilization, was being administered to some degree.

Clinical data suggests that fractures of the radius and ulna are extremely common in modern human populations. Accurate reduction of these fractures is functionally vital; even slight displacement on healing may disturb the relationship between the radius and ulna and impair rotation of the forearm. Delayed or non-union of these long bones is also common, especially at the junction of the mid and distal thirds of the ulna shaft. In cases of marked malunion, subluxation of the inferior radio-ulna joint may occur. Reduction and immobilization in a plaster cast is the standard treatment in clinical contexts, except in cases such as Smith's fracture (a fracture of the distal end of the radius with anterior displacement), which must be corrected operatively due to its unstable nature.

The majority of fractures to the ulna (10/11) and radius (10/10) in the St. Helen-on-the-Walls population occur to the mid and distal shafts. In four instances the ulna and radius appear to have been fractured together. In three of these cases the fractures to both bones are well healed with no deformity or osteoarthritis. In one case of radius and ulna fracture, healing did not take place. Localized periosteal reaction is present in one individual with healed radius and ulna fractures. The successful healing of these bones is particularly surprising in light of the instability that fractures of these two bones cause. It appears highly likely that treatment was sought and successfully administered in these cases.

This is not necessarily true for instances when only one bone was fractured. In cases of radial fracture, seven out of ten instances displayed deformity of the bone, while only

one out of eleven cases of fracture to the ulna resulted in deformity. Connolly (1988) suggests that modern mid-shaft fractures of the ulna are easy to reduce. This may suggest that in instances when the ulna was fractured in medieval populations the radius successfully served as a natural splint or that the nature of the fracture insured that treatment would be particularly successful. The same, however, does not appear to be true in instances when only the radius was fractured.

The pattern of osteoarthritis substantiates this contention Arthritic lipping was noted on the articular facets of 70% of the radii displaying fracture. It appears, then, that rarely did a fracture of a radius successfully heal without deformity and subsequent development of arthritis in the adjacent joints as a sequel to the trauma. The instability of this bone when fractured, due to its rotation around the ulna when not immobilized, resulted in deformity and osteoarthritis. This finding suggests that either treatment of this fracture was usually unsuccessful or that when the radius was fractured immobilization was not practiced.

Fractures to the tibia and fibula are also common in modern populations. Reduction and immobilization is standard treatment for these fractures. Fibula fractures without associated tibial fractures are rare and often do not require intervention because of the natural splint that the tibia provides. Delayed or non-union of the tibia and fibula is a common complication. The distal shafts are particularly vulnerable due to the lack of surrounding soft tissues in the lower leg, reducing the amount of blood coming from the soft tissue (Rhinelander, 1974). Malunion may lead to osteoarthritis of the knee and/or ankle joints because of changed mechanical stress.

Six instances of fracture of the tibia and fibula were noted in the St. Helen-on-the-Walls population. The distal ends are the most prevalent location for fracture. There are four cases within this population of the tibia and fibula being fractured together; two of these instances appear within the same individual. Perplexingly, while the fractures in this individual were well healed, the trauma to the right side resulted in substantial deformity and osteoarthritis, while the fractures of the tibia and fibula of the left side healed with virtually no deformity. In total, half of the cases of fracture of the tibia (two out of four) and fibula (two out of four) in the St. Helen's population resulted in deformity. The relatively small number of fractures to these bones, along with the varying results, precludes a determination of the presence of treatment for these fractures. Similarly, the varying rate of periosteal reaction in the bones (tibia 33% and fibula 67%) may be an artifact of small sample sizes rather than a clear indication that the fibula was more susceptible to compound fracture (and therefore infection) than the tibia.

Only one case of fracture of the femur was noted in the St. Helen-on-the-Walls population. This oblique, mid-shaft fracture displayed linear deformity and no signs of osteoarthritis or periosteal reaction. The particularly low prevalence of fracture to this bone does not appear to be uncommon within medieval archeological populations from Britain (Table 6). Further, it implies that the femur was as unlikely a candidate for fracture in medieval urban populations as it is, reported by Buhr and Cooke (1959) and Fife and Barancik (1985), in modern populations.

The analysis of periosteal reaction and osteoarthritis associated with fractures may also be used to indirectly detect the availability and/or efficacy of medical treatment. The data from the St. Helen-on-the-Walls population suggests that periosteal reaction was present in 31.7% of the bones displaying fractures. This proportion appears to be low in light of the historical data indicating the unsanitary conditions in York. Similarly, Grauer (1993) has suggested that the high proportion of adults in the skeletal population displaying remodeled periosteal reaction (77%) may indicate the presence of chronic infectious agents affecting the population. It is surprising, therefore, that only 31.7% of the fractured bones of adults display pathological change associated with the presence of infection. Two reasons for this pattern are offered: the prevalence of compound fracture in the St. Helen-on-the-Walls population was low (thereby not exposing the bone or internal tissue to the environ-

ment), or attempts at intervention were made and often were successful.

Population comparisons

Comparisons of fracture patterns highlighted several trends and suggest that St. Helen-on-the-Walls was similar to other medieval urban skeletal populations. First, long bone fractures appear to be uncommon in all populations examined. The higher frequency found in St. Nicholas Shambles is likely due to poor long bone preservation, since the percentage of long bones available for examination per individual was low. The higher percentage of adults with fractures at Chichester Hospital is likely due to the unusual nature of hospital cemetery samples. Second, the radius and/or humerus are the most commonly fractured bones. Lastly, the higher number of males displaying long bone fractures at St. Helen's is corroborated by the same trend in every other population examined. Although fracture healing patterns were not examined in the comparative groups, the overall trends in fracture frequency and type suggest that hazards in medieval urban centers were similar. Future research into healing patterns will provide greater insight into the availability of treatment throughout Britain and the effects of varying socioeconomic environments.

CONCLUSIONS

The analysis of patterns of long bone fractures in the St. Helen-on-the-Walls population has shown that virtually all detectable cases of fractures in adult skeletons were well healed. The majority of the fractures were well aligned and without substantial deformity. Of particular interest were the low numbers of deformity in bones likely to be severely affected by fracture, such as in the humerus and instances in which the radius and ulna were both fractured. The successful healing of these fractured bones implies that immobilization and possibly reduction was practiced. The analysis of the type of fracture suggests that trauma to the long bones was not attributable to heavy labor or violent activities. Males, however, in the St. Helen-on-the-Walls population, as well as in the comparative medieval populations, display twice the number of long bone fractures as females. In all, the patterns of fracture type, location, and healing suggest that some form of treatment was available for the poorest residents of York and, likewise, was often successful.

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